Case Study 42

Energy efficiency in higher education buildings: condensing gas boilers

Condensing gas boilers for heating in higher education buildings

- Running cost savings of 10-20%
- Paybacks under 5 years
- High efficiencies using conventional system design
- Easy to install and maintain
- Environmentally friendly

Overview

On average, higher education buildings use about 3300 kWh/student per year or 190 kWh/m^2 per year in providing space heating and domestic hot water. This can account for around 65% of the total energy used in this type of building. Potentially it is one of the most controllable overheads in any education budget. Overall responsibility for saving energy, minimising environmental damage and reducing expenditure, lies with the directors of these establishments. One of the best ways to address these issues is to install condensing gas boilers. This results in savings of 10-20% in the annual fossil fuel bill and a corresponding reduction in harmful emissions to the atmosphere.

On a national basis, heating and hot water costs higher education establishments roughly £60 million each year which represents a large part of their total expenditure on energy. If only one-third of the existing boiler plant were to be replaced by condensing boilers then conservative estimates indicate that this measure alone would save £2 million each year. In general, the necessary additional investment would be repaid in less than five years.

Overall energy consumption in higher education results in around 2.2 million tonnes of CO_2 being emitted into the atmosphere every year, thus adding to the greenhouse effect. Of this, about 1 million tonnes can be attributed to space heating and domestic hot water. Using condensing boilers could reduce this by 33 000 tonnes/yr and would also help prevent acid rain.

This technology provides a cost-effective way of reducing pollution and conserving natural resources. Examples of good practice using condensing boilers in higher education buildings are discussed in this Case Study. The results show that condensing boilers can offer very attractive investment opportunities in a wide range of circumstances.

HIGH SCHOOL YARDS, EDINBURGH UNIVERSITY

Edinburgh University was founded in 1583 and its estate is made up mainly of Georgian buildings and modern air-conditioned teaching blocks. The total floor area is 400 000 m^2 and provides facilities for over 14 000 students. This Case Study represents a part of the University known as the High School Yards complex. This houses the Geography Department with an advanced computer centre, alongside the Department of Dentistry. The buildings provide teaching and research facilities including seminar rooms and lecture theatres, workshops, laboratories, and offices for about 40 staff.

The complex consists of three buildings which vary between two and three storeys forming a courtyard at their centre. They are all of heavyweight sandstone constructions with pitched slate roofs and single glazed wooden frame windows.

System

Heating was previously supplied by two, very old, coal-fired, Lancashire steam boilers, each rated at 4000 lbs/hr. They suffered from heavy emissions of soot and were difficult to control. This led to a poor match between output and demand, resulting in high energy consumption. To meet the demand, they were normally fully manned and operated 24 hours a day. To improve efficiency, the old direct steam

High School Yards, Edinburgh University

Chemistry block, Keele University

Oxford Brookes University

"Condensing boilers can offer very attractive investment opportunities in a wide range of circumstances"

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system was gradually replaced by low temperature hot water (LTHW) circuits and calorifiers. The new central boilers were installed in the summer of 1988. Three Atlantic boilers were installed comprising one Condensagaz condensing boiler rated at 349 kW and two Optimagaz high efficiency boilers rated at 232 kW each. They have low standing losses and are particularly compact, thus releasing a considerable amount of space in the old boiler room and coal storage area.

At this stage, the old calorifiers were removed to form the modern boiler room and the new gas-fired boilers were connected directly to the existing radiator heating systems.

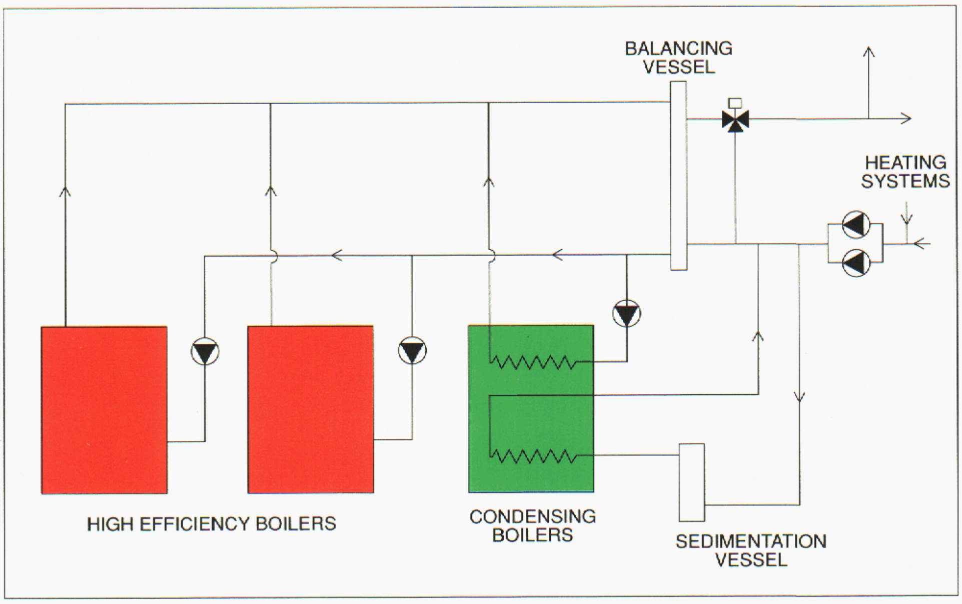
A sequence controller ensures that the more efficient condensing unit always operates as the lead boiler and that the overall output is controlled in relation to the demand for heat. At the time of writing, the condensing boiler has fired for a total of over 4800 hours whereas the high efficiency conventional boilers have fired for only 1450 hours each, thus indicating that the highly efficient condensing boiler supplies the base load. An optimiser varies the overall length of the heating period each day, thus minimising energy usage. The heating circuits are divided into two zones. These are controlled by one weather compensator which acts on a single three-port valve. Operation is normally 07.30-16.30 for 5 days per week from late September through to June. However, the University does not begin its heating season at a specific time; it normally waits until the onset of cold weather.

The High School Yards complex is made up of grade I listed buildings. Consequently, a specifically designed fan diluted flue was installed to blend with the surrounding architecture. This would also have been done had a conventional boiler been installed. The flue is constructed of stainless steel specifically to resist the slightly corrosive nature of the condensate from the condensing boiler. Three separate 200 mm flues rise into a fan dilution header fitted with three fans. The three fans are sequenced in conjunction with the operation of the boilers. This ensures that the correct pressures are maintained in the flue depending upon the number of boilers operating. The condensate is run to an external drain of standard plastic pipe. The boiler has an integral stainless steel trap to prevent combustion products discharging into the boiler room.

Economics

The annual consumption has dropped from 2 291 700 kWh for the old installation to 917 200 kWh with the new boilers; as a result the scheme won a Gas Energy Management (GEM) award from British Gas. The overall modernisation programme has therefore resulted in a 60% saving in fuel consumption. This was due to an integrated package of measures including the move from steam to LTHW, improved controls and a combination of high efficiency and condensing boilers.

The University Engineer originally anticipated a payback of around 4 years for the condensing boiler. This has been confirmed by recent gas consumptions. Based on overall additional costs of £5500 and an estimated 10% fuel saving due solely to the condensing boiler, the actual payback is calculated at 4.6 years.



Schematic of heating system at High School Yards, Edinburgh University

Reactions

The University Engineer originally decided to install a condensing boiler to reduce running costs and was closely involved in the design and installation of the new boiler plant. He is therefore well placed to give a view on the overall process. He feels that the design was relatively straightforward and the installation and commissioning proved to be very easy. Maintenance is simple and he says that there are no extra maintenance costs involved with condensing boilers over those for non-condensing boilers. Reliability has been very good. He would definitely use condensing boilers again in other buildings. Overall, the University staff are very pleased with the reliability and performance of this highly efficient installation.

CHEMISTRY BLOCK, KEELE UNIVERSITY

Founded as a college in 1949, Keele acquired university status in 1962. The 400 acre campus accommodates around 5500 students and is situated near Newcastle under Lyme in Staffordshire. The site previously had three extensive district heating schemes which were phased out in the mid-1980s to reduce system losses. This provided an ideal opportunity to introduce a range of energy efficient measures. These included eight separate plant rooms with condensing boilers, one of which also has a combined heat and power (CHP) unit.

This Good Practice Case Study focuses on the boiler plant situated in the Chemistry block which supplies up to 3 MW of space heating to eight major science buildings. In general, these are 2-, 3- and 4- storey buildings constructed in the 1950s and 60s with flat roofs and extensive single glazed areas. The system supplies heat to over 21 000 m^2 of floor space in the Physics, Geology, Biology, and Neuroscience buildings, the Computer Centre and the Chemistry block

Edinburgh University boilers

itself. The buildings are mainly laboratories and lecture theatres with some staff office space. They accommodate up to 2000 staff and students. Occupancy is generally 5 days per week from 08.30 to 19.00 with intermittent evening classes up to 21.00.

System

Three natural-draught Broag Seagold GAS 6A-16HE gas-fired condensing boilers were installed in the Chemistry boiler house in the summer of 1987. Each boiler has an output of 1013 kW and all three supply space heating only. Each boiler has a high/low fire facility switched by a sequence controller. This improves the efficiency by closely matching the boiler firing to the demand for heat. As recommended by Broag, all three boilers go to low fire before any are allowed to switch to high fire. The firing sequence is rotated regularly to even out wear on the plant. At the time of writing, each of the boilers has run for 4000-5000 hours at low fire and 750-850 hours at high fire. The reverse return primary water circuit has been kept as short as possible in order to minimise heat losses. In order to maximise summer hot water efficiencies, domestic hot water (DHW) for the Chemistry block is supplied separately by two direct fired storage water heaters.

The heating systems are primarily radiators and natural convectors but there is also a mixture of mechanical ventilation systems, radiant panels and unit heaters. A central weather compensator acts directly on the boilers to provide a coarse temperature control in relation to the external temperature. There are ten circuits to the buildings, some of which are individually controlled by separate weather compensators acting on three-port valves. This provides fine control on the radiator circuits, and hence energy savings, whilst still supplying the somewhat higher temperatures necessary for air heating and radiant panel systems. The return water is therefore at a mixed temperature that is still low enough to make the boilers condense for much of the year.

Each boiler has a condensate drain made of standard plastic waste pipe with a trap to avoid combustion products discharging into the plant room. There is also an inspection point to allow a visual check on the level of condensate. The flue system combines in the boiler room to form a single vertical chimney which is more compact than that for conventional boilers. It is constructed of twin wall stainless steel in order to resist the mild acidity of any condensate which may form in the flue. The flue has a separate condensate drain to accommodate this.

Economics

The Chemistry block boiler house installation was designed by the Maintenance Manager and it is operating to his expectations. His original estimate of a three year payback period has been confirmed. With a current gas cost now under £32 000 per annum, the additional cost of the condensing boilers has been paid back in just over three years. The payback would have been even quicker had the third boiler, which is only required for peak loads, been conventional plant. A mix of condensing and conventional boilers would have significantly reduced the capital cost of the installation resulting in only a small reduction in efficiency, thus improving the payback. The savings of £5500 each year now go back into the University's budget for additional expenditure.

Keele University

Reactions

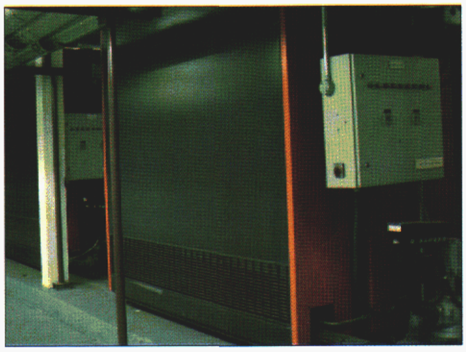
The Maintenance Manager has made a conscious effort to introduce energy efficiency at every opportunity. This has also included zone control, weather compensation and CHP. He is very satisfied with all the condensing boiler installations on the site and would always seek to use them in the future. Installing and commissioning these boilers was no more complicated than for conventional plant and he has generally found them to be easy to maintain with no extra cost implications. The eight separate condensing boiler plants on site have all proved to be very reliable – especially the Chemistry block boilers.

OXFORD BROOKES UNIVERSITY

The Oxford Brookes University, formerly Oxford Polytechnic, can trace its origins back to 1865 when it was a school of art. In 1976 it amalgamated with a teacher training college based at Wheatley and is now located on two sites.

The main Gipsy Lane Campus in Headington was built between 1953 and 1975 whereas the Wheatley Campus, situated 5 miles away, was built between 1974 and 1988. The University has about 1500 staff serving over 11 000 students. Many of the teaching facilities and residences are used out of term time for external conferences, and teaching often goes on until 21.00 throughout the whole of the year.

In recent years it became difficult to maintain the sprawling mains of the centralised heating system and energy consumption was high due to losses from the system. A central theme throughout a programme of decentralisation, which began in 1990, has been the installation of over 119 condensing boilers in 14 plant rooms at Wheatley Campus and 17 plant rooms at the Gipsy Lane Campus. The Deputy Buildings Officer responsible for energy management instigated the decentralisation in order to reduce energy costs. He carried out the design of the new systems himself, with support from the boiler suppliers. He is so pleased with the condensing boilers that work is in progress to install 30 more in halls of residence.



Keele University boilers

System

Space is at a premium on the sites and this is just one of the reasons why the compact Microstar boilers were chosen. In some cases, this avoided building new plant rooms as part of the decentralisation, keeping capital costs to a minimum.

The boilers are installed in a whole range of building types including teaching blocks, student accommodation, common rooms, a laundry block and a business centre. Many of the residential blocks have, for example, eight wall hung 20 kW gas-fired Yorkpark Microstar boilers. All the heating systems are controlled by a central building energy management system (BEMS). This allows close monitoring, tight control and, ultimately, improvements in comfort conditions and reductions in energy consumption and/or costs. This is directly linked to monitoring and targeting software which allows a whole range of sophisticated techniques including trend logging and regression analysis. There are numerous gas and electricity meters installed across the site in order to allow invoicing for conferences and seminars. This also allows the estates staff to keep a close watch on consumption trends in order to identify any problems very quickly.

Each plant room has an optimum start/stop control set in order to meet the requirements of the teaching staff. Sequence control matches the boiler firing to the load, essentially making each plant room one large modular boiler system. Each of these is weather compensated which reduces the return water temperature when the outside temperature is mild. This overall energy saving control package, resulting in higher operating efficiencies, makes the boilers condense in the milder months of Spring and Autumn. Further control of the space temperatures is achieved using zone valves throughout each building. The new hot water systems in the student accommodation blocks have high capacity calorifiers which ensure that heat up times are very fast. This generally provides low return water temperatures and thus increased efficiencies.

	Estimated annual running cost (conventional system) £	Estimated annual running cost saving (condensing element) £	Estimated percentage saving %	Overcost (condensing element) £	Approximate payback period (condensing element) years
High School Yards Edinburgh University	11 900	1200	10	5 500	4.6
Chemistry block, Keele University	37 100	5500	15	18 100	3.3
Oxford Brookes University (C block)	8 700	1370	16	4 800	3.5

Estimated economics of the condensing boiler installations compared to new all conventional systems, the original plant having come to an end of its useful life. In all cases savings are quoted on the basis of the same useful heat delivered to the building, ie room temperatures are unaffected. The estimated savings shown take into account system design factors.

The majority of the boilers have balanced flues although, where this has not been practical, horizontal monodraught flues have been installed. Condensate drains are run in ordinary plastic waste pipe and each boiler has an integral trap to stop combustion gases reaching the plant room. The drain also has an open tundish to allow a visual inspection of the flow of condensate – a prime indication of high efficiency.

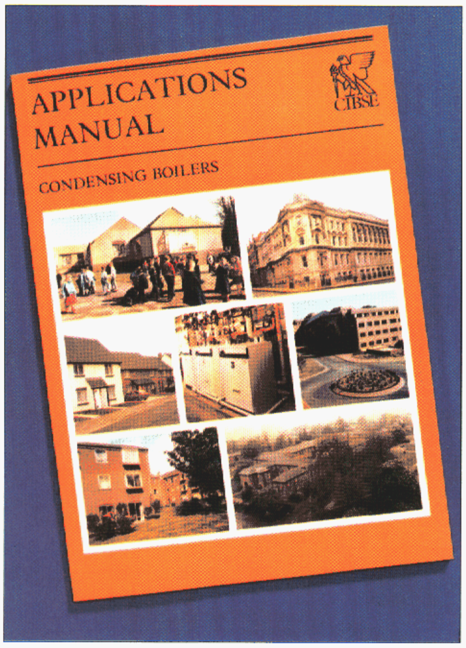
Economics

The University has achieved major savings due to the programme of decentralisation and the associated improvements in control. The condensing boilers have been a key part of this strategy. The Deputy Buildings Officer originally anticipated payback periods for the condensing boilers between 3 and 5 years. This depends on the occupancy hours of the building. The residential blocks have higher occupancy and therefore a better payback period. Taking Teaching Block C as an example, it is estimated that the additional investment will be recovered in around 3.5 years. Considering this is a relatively low occupancy building, this is a very good return on investment and in line with previous expectations. It seems highly likely, therefore, that the payback in the residential blocks will be well under two years.

Reactions

Decentralising the main boiler plant meant that the staff operating the central boilers could be re-trained as general boiler maintenance staff. This has improved the operation of all the heating systems across each campus and in particular they ensure that the condensing boilers are maintained to a high level. Standardisation of plant has helped this and has reduced the spares that need to be retained. The University's Deputy Buildings Officer commented that there is no additional maintenance compared to conventional plant, particularly if staff are trained properly. Good training leads to better maintenance which directly improves energy efficiency and reliability.

The decision to install a further 30 condensing boilers in halls of residence indicates both the success of the plant and the satisfaction of the estates staff. They maintain that the lack of complaints about heating combined with low gas costs shows just how well the plant performs. They are expecting between 10 and 15 years life from the boilers which is about the same as conventional plant.



CIBSE Manual

CONCLUSIONS

These three Case Studies have shown that condensing boilers are a viable proposition in higher education buildings. They have provided energy savings of 10-16% and simple payback periods of 3-5 years. All the engineers concerned are happy and would install condensing boilers again. They have proved to be reliable and economic whilst maintaining comfortable conditions in the range of building types and uses on these university campuses.

Further information

This Good Practice Case Study is one of a series on the use of condensing boilers in various building sectors. Good Practice Guide 16 provides practical information on installing condensing boilers in large buildings. The Chartered Institution of Building Services Engineers (CIBSE) Applications Manual AM3: Condensing Boilers gives detailed guidance on all aspects of the subject. This covers appliance selection, new application yardsticks, system design and economic evaluation.

The information presented in this series of Case Studies has been taken from material provided by the users and from site visits carried out by independent consultants. Where possible, economic figures have been calculated from the fuel bill. Estimates have been made in cases where these were not available. The co-operation of the owners, designers, managers and occupants of the Case Study buildings is gratefully acknowledged.

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